TITLE OF THE INVENTION

INTERACTIVE NAVIGATION SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to navigation systems and, more specifically, to an interactive navigation system which comprises a mobile apparatus and a server, and which performs navigation by the mobile apparatus requesting the server to search for a route and the server sending a search result to the mobile apparatus.

Description of the Background Art

[0002] [Non-interactive navigation device]

Non-interactive navigation devices that have been conventionally used are exemplarily structured as shown in FIG. 18, which is disclosed in Japanese Patent Laid-Open Publication No. 5-216399 (1993-216339). In FIG. 18, a conventional non-interactive navigation device includes a map data storage 301, a vehicle position detector 302, a display part 303, a map scale selection switch 304, a map scale controller 305, a display controller 306, and a route search part 307.

[0003] In the above-structured navigation device, the map data storage 301 stores map data. The vehicle position detector 302 detects the present position of a vehicle in which the navigation

device is mounted thereon. The route search part 307 retrieves required map data from the map data storage 301 based on the present position detected by the vehicle position detector 302 (or, a starting point specified by a user) and a destination that is specified by the user, and searches for an optimum route. The display controller 306 causes the display part 303 to display at least the present position of the vehicle and the optimum route on a map.

[0004] The user can use the map scale selection switch 304 for selecting the scale of the displayed map. Based on the selection of the scale of the displayed map, the map scale controller 305 instructs the display controller 306 to access the map data of the selected scale. In response, the display controller 306 retrieves the map data of that scale from the map data storage 301. The display part 303 then displays a map based on the map data and overlays the present position of the vehicle on the map.

[0005] In the above-described non-interactive navigation device, a removable storage medium such as a CD-ROM or DVD is generally used as the map data storage 301. By replacing the entire medium with another medium, the map data can be updated. However, the map data is usually updated only once or twice a year, and therefore the map data cannot instantly reflect new events, such as the closing of streets due to maintenance, or an opening of a new road. The difference between the map data and the actual situations of the roads often disables appropriate navigation.

[0006] [Conventional interactive navigation system]

To avoid the above-described problem, interactive navigation systems comprising a mobile apparatus and a server have been recently suggested. Navigation is carried out (performed) by the mobile apparatus requesting the server to search for a route and by the server sending a search result to the mobile apparatus. In such a newly suggested interactive navigation system, the server manages the map data. Therefore, the map data can instantly reflect road maintenance, the opening of a road, and other events, thereby enabling navigation with the actual road situations reflected thereon.

[0007] [Conventional route search method; Dijkstra's algorithm]

In the above-described non-interactive navigation device, the route search part 307 searches for the optimum route with Dijkstra's algorithm, which is now described below.

[0008] FIG. 19 is a diagram demonstrating an optimum-route search by using Dijkstra's algorithm. This optimum-route search is generally performed based on a route graph that is composed of nodes and links as shown in FIG. 19. A node corresponds to an intersection of roads, and a link corresponds to a section between the nodes on a road.

[0009] In the route graph of FIG. 19, a numerical value is assigned to each link. This numerical value is called a link length. The link length represents, for example, the length of the section

of the road, or a time it takes a vehicle to pass through that section at a legal speed. In FIG. 19, several routes can be thought from a point S to a point T. Of these routes, the optimum route is a route where there is a minimum total number of link lengths composing that route.

[0010] Therefore, the route search part 307 finds the optimum route where there is a minimum total number of link lengths composing that route from among a plurality of routes from the starting point (present position) to the destination.

[0011] In this method, however, the optimum route is found based on the time that is required when the vehicle travels at the predetermined speed, that is, the optimum route is found based on a fixed value. Therefore, it happens quite often that the vehicle runs into a traffic jam and arrives late.

[0012] [Route search method in consideration of traffic jam; Dijkstra's algorithm with weighting]

To get around this problem, navigation devices performing an optimum-route search in consideration of traffic jams have also been suggested. Traffic jam information is externally provided by, for example, VICS (Vehicle Information and Communication System) (see "automobile traffic system for the 21st century", Sadao Takaba, Kogyo Chosakai Publishing Co., Ltd., pp. 95-97, 1998).

[0013] A route search in consideration of traffic jams is performed by Dijkstra's algorithm with weighting. FIG. 20 is a

diagram demonstrating an optimum-route search by using Dijkstra's algorithm with weighting. In a route graph shown in FIG. 20, several links are provided with a weight "aij" provided onto the previously assigned link length. If the link length represents the time that is required for the vehicle to pass through the link, the weight "aij" to be provided to the link length represents time in proportion to a degree of traffic jam. With such a weight provided to the link, the time that is required for actually traveling the road section can be represented more accurately.

[0014] Such a route search by using the route graph with weighting can find an optimum route more accurately as compared with the route search by using Dijkstra's algorithm without weighting. The optimum route is a route the vehicle can travel in a minimum period of time. If the vehicle follows the route found with this method, the vehicle will be less likely to run into a traffic jam and arrive late.

[0015] [Problem in the interactive navigation system]

In the interactive navigation system, the server carries out a route search, and then not only transmits the search results to the mobile apparatus but may also transmit thereto various map data, information related to the map data (traffic jam, attractions, and events, for example) to the mobile apparatus. When the server transmits the map data and the related information to the mobile apparatus, the server has to bill a user of the mobile apparatus at an appropriate amount of charge (billing information). However,

a billing method for this case has not been known.

[0016] Therefore, a first object of the present invention is to provide a method of billing a mobile apparatus for provided map data and related information at an appropriate charge, and an interactive navigation system that carries out (performs) such billing.

[0017] [Problem in the route search method in consideration of a traffic jam]

The externally provided traffic jam information only indicates the situations of a traffic jam at one previous time. When the vehicle actually travels the road, the situations of traffic jam may possibly be different from those situations that are indicated by the traffic jam information. In other words, the route search in consideration of the externally provided traffic jam information only finds an optimum route at one previous time. Therefore, it may still happen that the vehicle runs into a traffic jam and arrives late.

[0018] Therefore, a second object of the present invention is to provide a navigation system that can more accurately find an optimum route when the vehicle actually travels a road and, as a result, more ably prevent a vehicle from running into a traffic jam and arriving late.

SUMMARY OF THE INVENTION

[0019] The present invention has the following features to

achieve the objects described above.

[0020] A first aspect of the present invention is directed to an interactive navigation system which comprises a mobile apparatus and a server and which carries out (performs) navigation by the mobile apparatus by requesting the server to search for a route and the server transmitting a search result to the mobile apparatus.

[0021] The mobile apparatus of the first aspect comprises an input part for inputting at least a destination, and a first transmitter for transmitting a packet including at least the destination inputted by the input part to the server.

[0022] The server of the first aspect comprises: a map data storage for storing map data;

a first receiver for receiving the packet transmitted by the first transmitter;

a route search part for searching for the route based on the destination included in the packet received by the first receiver and the map data stored in the map data storage;

a map data selector for selecting, from among the map data stored in the map data storage, only map data including the route that is found by the route search part;

a billing part for holds a price list (refer to FIG. 7 including unit prices for the map data stored in the map data storage, for calculating an amount of charge for the map data selected by the map data selector based on the price list, and for generating billing information including at least the amount

of charge; and

a second transmitter for transmitting, to the mobile apparatus, a packet including at least the route found by the route search part, the map data selected by the map data selector, and the billing information generated by the billing part.

[0023] In the first aspect (or tenth to twelfth aspects described below), the mobile apparatus transmits a packet including at least a destination inputted by the user to the server. The server receives the packet.

[0024] The server stores map data, and performs a route search based on the destination included in the received packet and the stored map data. Then, the server selects, from among the stored map data, only the map data including the route found by the route search part.

[0025] The server also holds a price list including unit prices for the map data stored in the map data storage. Such unit prices include a price per sheet of map and a price per unit amount of information. Based on the price list, the server calculates the amount of charge for the selected map data, and generates billing information including at least the amount of charge. Then, the server transmits a packet including at least the found route, the selected map data, and the generated billing information to the mobile apparatus.

[0026] Thus, it is possible to bill the user of the mobile apparatus at the charge (in proportion to the number of sheets

or the data amount, for example) based on the map data transmitted to the mobile apparatus.

[0027] In addition, the length of the route found by search varies for each search. For example. a route from Osaka to Kobe is entirely different in length from that from Osaka to Fukuoka. Moreover, several routes can be thought from one starting point to one destination, and such routes vary in length from one another. Therefore, the number of sheets of maps based on the map data and the amount of map data vary according to the route taken.

[0028] Therefore, in the first aspect, a route search is performed in response to a request from the mobile apparatus, map data including the route found by the search is selected, and the amount of charge according to the number of sheets of map and the amount of data is billed to the mobile apparatus. In this case, the user of the mobile apparatus pays only for the map data transmitted thereto.

[0029] According to a second aspect, in accordance with the first aspect, the mobile apparatus further comprises

a second receiver for receiving the packet transmitted by the second transmitter, and

a route guide part for performing a route guide based on the route included in the packet received by the second receiver and the map data.

[0030] In the second aspect, the mobile apparatus receives the packet transmitted by the server. Then, the mobile apparatus

carries out a route guide based on the route included in the received packet and the map data.

[0031] According to a third aspect, in accordance with the first aspect, the mobile apparatus further comprises a present position detector for detecting a present position of the mobile apparatus, the packet transmitted by the first transmitter further includes the present position detected by the present position detector, and, based on the present position and the destination included in the packet received by the first receiver and the map data stored in the map data storage, the route search part searches for the route from the present position and the destination.

[0032] In the third aspect, the mobile apparatus detects its present position, and transmits a packet including the detected present position. The server searches for a route from the detected present position and the destination based on the detected present position and destination included in the received packet and the stored map data.

[0033] According to a fourth aspect, in accordance with the first aspect, a starting point is inputted by the input part, the packet transmitted by the first transmitter includes the starting point inputted by the input part, and, based on the starting point and the destination included in the packet received by the first receiver and the map data stored in the map data storage, the route search part searches for the route from the starting point and the destination.

[0034] In the fourth aspect, the mobile apparatus transmits a packet including the destination inputted by the user to the server. The server searches for a route from the starting point to the destination based on the starting point and destination included in the received packet and the stored map data.

[0035] According to a fifth aspect, in accordance with the first aspect, the server further comprises a related information storage for storing related information relating to the map data stored in the map data storage, and the price list held by the billing part includes a unit price for the related information stored in the related information storage. Further, according to the fifth aspect, the billing part calculates an amount of charge for related information relating to the map data selected by the map data selector and adds the calculated amount of charge to the billing information, and the packet transmitted by the second transmitter further includes the related information relating to the map data selected by the map data selector.

[0036] Thus, it is possible to bill the user of the mobile apparatus at the charge (in proportion to the number of areas or the data amount, for example) based on the related information transmitted to the mobile apparatus.

[0037] Here, as described above, the route found by search varies for each search. Therefore, the number of sheets of map and the amount of data that is required for the route guide vary according to the route taken, and the information related to the

map data varies accordingly.

[0038] Therefore, in the fifth aspect, a route search is carried out in response to a request from the mobile apparatus, and map data including the route found by search is selected. Then, the amount of charge for the map data according to the number of sheets of map and the amount of data, and the amount of charge for the related information according to the number of areas and the amount of data is billed to the mobile apparatus. In this case, the user of the mobile apparatus pays only for the map data and related information transmitted thereto.

[0039] According to a sixth aspect, in accordance with the fifth aspect, the mobile apparatus further comprises a presenter for presenting the related information that is included in the packet received by the second receiver of the mobile apparatus.

[0040] In the sixth aspect, the related information included in the received packet is presented. For example, the related information includes, as in the following seventh aspect, traffic jam information as to the roads in the area corresponding to the map data. Alternatively, the related information may include events and discount sales held in that corresponding area, or sightseeing spots therein. Presentation of the related information is performed through a display and/or a speaker in the mobile apparatus.

[0041] According to a seventh aspect, in accordance with the sixth aspect, the related information includes traffic jam

information for roads in an area that corresponds to the map data, and the billing part calculates an amount of charge for the traffic jam information as the amount of charge for related information relating to the map data selected by the map data selector.

[0042] In the seventh aspect, when the related information includes traffic jam information, the server calculates, as the amount of charge for the information related to the selected map data, the amount of charge for the traffic jam information as to the roads in the area corresponding to the map data. For example, if the user of the mobile apparatus selects data for two sheets of a map, the server calculates the amount of charge for the traffic information as to the roads in the areas corresponding to these two sheets of the map, and adds the amount of charge to the billing information. Then, the server transmits the traffic information for the two areas together with the map data for the two sheets of the map.

[0043] According to an eighth aspect, in accordance with the first aspect, a registration identifier is further inputted by the input part, and the packet transmitted by the first transmitter further includes the registration identifier inputted by the input part. Further, according to the eighth aspect, the server further comprises a registration check part which holds a registration check list including at least all valid registration identifiers, for determining whether the registration identifier included in the packet received by the first receiver is in the registration

check list, and the route search part performs the route search only when the registration check part determines that the registration identifier is in the registration check list.

[0044] In the eighth aspect, unregistered members cannot use the system without paying the charge.

[0045] According to a ninth aspect, in accordance with the first aspect, the map data storage stores a plurality of map data of different forms for use in displaying a same map, a registered data form is further inputted by the input part, and the packet transmitted by the first transmitter further includes the registered data form inputted by the input part. Further, according to the ninth aspect, the registration check list held by the registration check part includes the registered data form that corresponds to a registered identifier, and the map data selector selects, from among the map data stored in the map data storage, only map data including the route found by the route search part and complying with a registered data form that is included in the packet received by the first receiver.

[0046] In the ninth aspect, the mobile apparatuses varying in map data form can be each provided with the map data of each appropriate form.

[0047] A tenth aspect of the present invention is directed to a server which searches for a route in response to a request from a mobile apparatus and which transmits the route found by the search to the mobile apparatus.

The mobile apparatus of the tenth aspect comprises an input part for inputting at least a destination, and a first transmitter for transmitting a packet including at least the destination inputted by the input part to the server.

[0048] The server of the tenth aspect comprises:

a map data storage part for storing map data;

a first receiver for receiving the packet transmitted by the first transmitter;

a route search part for searching for the route based on the destination included in the packet received by the first receiver and the map data stored in the map data storage part;

a map data selector for selecting, from among the map data stored in the map data storage part, only map data including the route that is found by the route search part;

a billing part for holding a price list including unit prices for the map data stored in the map data storage, for calculating an amount of charge for the map data selected by the map data selector based on the price list, and for generating billing information including at least the amount of charge; and

a second transmitter for transmitting, to the mobile apparatus, a packet including at least the route found by the route search part, the map data selected by the map data selector, and the billing information generated by the billing part.

[0049] An eleventh aspect of the present invention is directed to an interactive navigation method of carrying out (performing)

navigation by searching for a route in response to a request from a mobile apparatus and by transmitting the route found to the mobile apparatus.

[0050] The mobile apparatus of the eleventh comprises an input part for inputting at least a destination; and a transmitter for transmitting a packet including at least the destination inputted by the input part to the server.

[0051] The method of the eleventh aspect:

a map data storing step of storing map data;

a receiving step of receiving the packet transmitted by the transmitter;

a route searching step of searching for the route based on the destination included in the packet received in the receiving step and the map data stored in the map data storing step;

a map data selecting step of selecting, from among the map data stored in the map data storing step, only map data including the route that is found in the route searching step;

a billing step of calculating an amount of charge for the map data selected in the map data selecting step based on a price list including unit prices for the map data stored in the map data storing step, and generating billing information including at least the amount of charge; and

a transmitting step of transmitting, to the mobile apparatus, a packet including at least the route found in the route searching step, the map data selected in the map data selecting

step, and the billing information generated in the billing step.

[0052]] A twelfth aspect of the present invention is directed to a program that describes an interactive navigation method of performing navigation by searching for a route in response to a request from a mobile apparatus and by transmitting the route found to the mobile apparatus.

[0053] The mobile apparatus of the twelfth aspect comprises an input part for inputting at least a destination, and a transmitter for transmitting a packet including at least the destination inputted by the input part to the server,

[0054] The method of the twelfth aspect comprises:

a map data storing step of storing map data;

a receiving step of receiving the packet transmitted by the transmitter;

a route searching step of searching for the route based on the destination included in the packet received in the receiving step and the map data stored in the map data storing step;

a map data selecting step of selecting, from among the map data stored in the map data storing step, only map data including the route that is found in the route searching step;

a billing step of calculating an amount of charge for the map data selected in the map data selecting step based on a price list including unit prices for the map data stored in the map data storing step, and generating billing information (refer to FIG. 8) including at least the amount of charge; and

a transmitting step of transmitting, to the mobile apparatus, a packet including at least the route found in the route searching step, the map data selected in the map data selecting step, and the billing information generated in the billing step.

[0055] A thirteenth aspect of the present invention is directed to an interactive navigation system which comprises a plurality of mobile apparatuses and a server and which performs navigation by one of the mobile apparatuses requesting the server to search for a route and by the server transmitting a search result to the requesting mobile apparatus.

[0056] Each of the mobile apparatuses of the thirteenth aspect comprises an input part for inputting at least a destination, a present position detector for detecting a present position of the mobile apparatus, and a first transmitter for transmitting a packet including at least the destination inputted by the input part and/or the present position detected by the present position detector to the server.

[0057] The server of the thirteenth aspect comprises:

a map data storage for storing map data;

a first receiver for receiving the packet transmitted by the first transmitter;

a route search part for searching for a route, if the packet received by the first receiver includes the destination, based on the destination and the map data stored in the map data storage; and

a second transmitter for transmitting a packet including at least the route found by the route search part to the mobile apparatus.

[0058] The route search part is operable to:

hold a mobile apparatus position/route management table for recording and managing the present position of each of the mobile apparatuses and the route found for each of the mobile apparatuses;

find a plurality of reachable routes to the destination when the packet received by the first receiver includes the destination;

sequentially calculate, for each of the found reachable routes, a time when a target mobile apparatus will pass at a predetermined speed along the route through each link composing the reachable route;

calculate, for each link, a number of presumed passing apparatuses that indicates how many mobile apparatuses will pass through the link simultaneously when the target mobile apparatus will pass through the link based on the present position of the mobile apparatuses other than the target mobile apparatus and the route recorded in the mobile apparatus position/route management table;

calculate a weight to be provided to each link based on the number of presumed passing apparatuses calculated for each link; and

search for the route based on a route graph with each link provided with at least the weight calculated based on the number of presumed passing apparatuses.

[0059] In the thirteenth aspect (or fifteenth and sixteenth aspects described below), the server holds a mobile apparatus position/route management table for recording and managing the present position of each of the mobile apparatuses and the route found for each of the mobile apparatuses.

[0060] The mobile apparatus for search (hereinafter, a target mobile apparatus) transmits a packet including at least the destination to the server. The other mobile apparatuses (hereinafter, non-target mobile apparatus) each detect its own present position, and transmit a packet including at least the detected present position to the server under a predetermined timing (several times per second periodically, for example).

[0061] The server stores the map data, and receives the packet transmitted by the mobile apparatus. If the received packet includes the destination, the server performs a route search based on the destination and the stored map data. Then, the server transmits a packet including at least the route found by the search to the destination.

[0062] During the route search, the server first finds a plurality of reachable routes. Then, the server sequentially calculates, for each of the found reachable routes, a time when a target mobile apparatus will pass at a predetermined speed along

the route through each link composing the reachable route. Then, the server calculates, for each link, a number of presumed passing apparatuses that indicates how many non-mobile apparatuses will pass through the link simultaneously when the target mobile apparatus will pass through the link based on the present position of the non-target mobile apparatuses and the route recorded in the mobile apparatus position/route management table. Then, the server calculates a weight to be provided to each link based on the number of presumed passing apparatuses that is calculated for each link. Then, the server searches for the route based on a route graph with each link provided with at least the weight calculated based on the number of presumed passing apparatuses.

[0063] As such, a route search is performed by using a route graph with each link provided with a weight calculated based on the number of presumed passing apparatuses for the road section (link) when the target mobile apparatus actually will pass through the road section. Therefore, as compared with a route search that uses a route graph based on only the traffic jam at a previous time, the optimum route when the mobile apparatus actually passes the road section is found more accurately.

[0064] According to a fourteenth aspect, in accordance with the thirteenth aspect, the server further comprises an input/output part connected to a communication line network. Further, according to the fourteenth aspect, the route search part is operable to:

further externally receive traffic jam information through the input/output part and the communication line network, and calculate a weight to be provided to each link based on the traffic jam information;

find the plurality of reachable routes based on a route graph with each link provided with the weight calculated based on the traffic jam information; and

search for the route based on the weight calculated based on the traffic jam information and the weight calculated based on the number of presumed passing apparatuses.

[0065] In the fourteenth aspect, a route search is performed by using a route graph with each link provided with a weight based on the traffic jam at previous time and a weight calculated based on the number of presumed passing apparatuses for the road section when the target mobile apparatus actually will pass through the road section. Therefore, the optimum route is found more accurately.

[0066] A fifteenth aspect of the present invention is directed to an interactive navigation method of performing navigation by searching for a route in response to a request from one of a plurality of mobile apparatuses and by transmitting the route found to the mobile apparatus.

Each of the mobile apparatuses of the fifteenth aspect comprises an input part for inputting at least a destination, a present position detector for detecting a present position of the

mobile apparatus, and a transmitter for transmitting a packet including at least the destination inputted by the input part and/or the present position detected by the present position detector to the server.

[0067] The method of the fifteenth aspect comprises:

a map data storing step of storing map data;

a receiving step of receiving the packet transmitted by the transmitter;

a route searching step of searching for a route, when the packet received in the receiving step includes the destination, based on the destination and the map data stored in the map data storing step; and

a transmitting step of transmitting a packet including at least the route found in the route searching step to the mobile apparatus.

[0068] In the route searching step, a mobile apparatus position/route management table is held for recording and managing the present position of each of the mobile apparatuses and the route found for each of the mobile apparatuses.

[0069] The route searching step further comprises:

a step of finding a plurality of reachable routes to the destination if the packet received in the receiving step includes the destination;

a step of sequentially calculating, for each of the found reachable routes, a time when a target mobile apparatus will

pass at predetermined speed along the route through each link composing the reachable route;

a step of calculating, for each link, a number of presumed passing apparatuses that indicates how many mobile apparatuses will pass through the link simultaneously when the target mobile apparatus will pass through the link based on the present position of the mobile apparatuses other than the target mobile apparatus and the route recorded in the mobile apparatus position/route management table;

a step of calculating a weight to be provided to each link based on the number of presumed passing apparatuses that is calculated for each link; and

a step of searching for the route based on a route graph with each link provided with at least the weight calculated based on the number of presumed passing apparatuses.

[0070] A sixteenth aspect of the present invention is directed to a program which describes an interactive navigation method of performing navigation by searching for a route in response to a request from one of a plurality of mobile apparatuses and by transmitting the route found to the mobile apparatus.

[0071] Each of the mobile apparatuses of the sixteenth aspect comprises an input part for inputting at least a destination, a present position detector for detecting a present position of the mobile apparatus, and a transmitter for transmitting a packet including at least the destination inputted by the input part and/or

the present position detected by the present position detector to the server.

[0072] The method of the sixteenth aspect comprises:

a map data storing step of storing map data;

a receiving step of receiving the packet transmitted by the transmitter;

a route searching step of searching for a route, when the packet received in the receiving step includes the destination, based on the destination and the map data stored in the map data storing step; and

a transmitting step of transmitting a packet including at least the route found in the route searching step to the mobile apparatus.

[0073] In the route searching step, a mobile apparatus position/route management table is held for recording and managing the present position of each of the mobile apparatuses and the route found for each of the mobile apparatuses.

[0074] The route searching step further comprises:

a step of finding a plurality of reachable routes to the destination if the packet received in the receiving step includes the destination;

a step of sequentially calculating, for each of the found reachable routes, a time when a target mobile apparatus will pass at predetermined speed along the route through each link composing the reachable route;

a step of calculating, for each link, a number of presumed passing apparatuses that indicates how many mobile apparatuses will pass through the link simultaneously when the target mobile apparatus will pass through the link based on the present position of the mobile apparatuses other than the target mobile apparatus and the route recorded in the mobile apparatus position/route management table;

a step of calculating a weight to be provided to each link based on the number of presumed passing apparatuses that is calculated for each link; and

a step of searching for the route based on a route graph with each link provided with at least the weight calculated based on the number of presumed passing apparatuses.

[0075] These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0076] FIG. 1 is a block diagram showing the structure of a interactive navigation system according to a first embodiment of the present invention;

FIG. 2A is a block diagram showing the hardware structure of a server 51 in the interactive navigation system according to the first embodiment of the present invention;

FIG. 2B is a block diagram showing the hardware structure of a mobile apparatus 52 in the interactive navigation system according to the first embodiment of the present invention;

FIG. 3A is a flowchart showing the operation of the mobile apparatus 52 in the interactive navigation system according to the first embodiment of the present invention;

FIG. 3B is a flowchart showing the operation of the server 51 in the interactive navigation system according to the first embodiment of the present invention;

FIG. 4 is a diagram showing the structure of a packet transmitted from the wireless transmitter/receiver 3 of the mobile apparatus 52 to the server 51;

FIG. 5 is a diagram showing a registration check list that is held by a registration check part 102;

FIG. 6 is a diagram exemplarily showing wide-area and detailed map data selectively read by a map data selector 105.

FIG. 7A is a diagram showing one example of a price list that is stored in a billing part 103, where the list includes unit prices of the map data per sheet;

FIG. 7B is a diagram showing another example of the price list including unit prices of related information;

FIG. 8A is a diagram showing one example of an amount of charge (billing information) calculated based on the price list of FIG. 7A;

FIG. 8B is a diagram showing another example of the amount

of charge (billing information) that is calculated based on the price list of FIG. 7B;

FIG. 9 is a diagram showing the structure of a packet transmitted from a wireless transmitter/receiver 101 of the server 51 to the mobile apparatus 52;

FIG. 10 is a block diagram showing the structure of an interactive navigation system according to a second embodiment of the present invention;

FIG. 11 is a block diagram showing the structure of an interactive navigation system according to a third embodiment of the present invention;

FIG. 12A is a flowchart showing the operation of a mobile apparatus 52a in the interactive navigation system according to the third embodiment of the present invention;

FIG. 12B is a flowchart showing the operation of a server 51a in the interactive navigation system according to the third embodiment of the present invention;

FIG. 12C is a flowchart showing the operation of non-target mobile apparatuses 52a in the interactive navigation system according to the third embodiment of the present invention;

FIG. 13 is a diagram showing the structure of a packet transmitted from a wireless transmitter/receiver 101 of the server 51a to the mobile apparatus 52a when billing is not performed;

FIG. 14 is a diagram showing a table that is held by a mobile apparatus position/route managing part 112;

FIG. 15 is a flowchart showing one detailed example of step S106a, as shown in FIG. 12B, wherein a route search part 104 searches for an optimum route;

FIG. 16 is a diagram demonstrating an optimum route search by the Dijkstra's algorithm using first and second weights, wherein the second weight "bij" is unique to the present invention;

FIG. 17 is a block diagram showing the structure of an interactive navigation system according to a fourth embodiment of the present invention;

FIG. 18 is a block diagram showing one example of the structure of a conventional non-interactive navigation system;

FIG. 19 is a diagram demonstrating an optimum route search by using Dijkstra's algorithm; and

FIG. 20 is a diagram demonstrating an optimum route search by using Dijkstra's algorithm with a weight.

DETAILED DESCRIPTION OF THE INVENTION

[0077] First embodiment

Hereinafter, an interactive navigation system according to a first embodiment of the present invention is described with reference to the drawings.

[0078] FIG. 1 is a block diagram showing the structure of the interactive navigation system according to the first embodiment of the present invention. In FIG. 1, the interactive navigation system includes a server 51 and a mobile apparatus 52. The mobile

apparatus 52 includes an operational input part 1, a present position detector 2, a wireless transmitter/receiver 3, a storage 4, a controller 5, a route guide part 6, an audio output part 7, a rendering part 8, a display part 9, a removable-medium drive 10, a received data decompression part 11, and an out-of-area determination part 12.

[0079] The server 51 includes a wireless transmitter/receiver 101, a registration check part 102, a billing part 103, a route search part 104, a map data selector 105, a map data storage 106, a transmission data compression part 107, a related information storage 108, an input/output part 109, a controller 110, and a transmission data history storage 111.

[0080] The mobile apparatus 52 and the server 51 can wirelessly communicate with each other. The server 51 can communicate, through a communication line network 122, with the outside such as a host computer in a traffic control center or in a financial institution (not shown).

[0081] FIG. 2A is a block diagram showing one example of the hardware structure of the server 51, and FIG. 2B is a block diagram showing one example of the hardware structure of the mobile apparatus 52, both according to the first embodiment.

[0082] In FIG. 2A, the server 51 includes a CPU 53, ROM 54, RAM 55, a large-capacity storage 56, and a wireless transmitter/receiver 57. A program for the server 51 is stored in the ROM 54. Following the program stored in the ROM 54, the

CPU 53 operates by using the RAM 55 as a working area to perform operations and to control other hardware, thereby realizing a function of each component shown in FIG. 1.

[0083] In FIG. 2B, the mobile apparatus 52 includes a CPU 58, ROM 59, RAM 60, a GPS receiver 61, a removable-medium drive 63 (CD-RW drive, for example) for a removable recording medium, a wireless transmitter/receiver 62 (such as a cellular phone, for example), a display 64, and a loudspeaker 65. A program for the mobile apparatus is stored in the ROM 59. Following the program stored in the ROM 59, the CPU 58 operates by using the RAM 60 as a working area to perform operations and to control other hardware, thereby realizing a function of each component shown in FIG. 1.

[0084] The operation of the interactive navigation system according to the first embodiment of the present invention will now be briefly described.

[0085] FIG. 3A is a flowchart of the operation of the mobile apparatus 52, and FIG. 3B is a flowchart of the operation of the server 51, both according to the first embodiment. The operation of the mobile apparatus 52 shown in FIG. 3A is realized by the controller 5 carrying out operations and controlling other components (1 to 4, and 6 to 12). The operation of the server 51 shown in FIG. 3B is realized by the controller 110 carrying out operations and controlling other components (101 to 109, and 111).

[0086] In FIG. 3A, the mobile apparatus 52 receives an input

concerning a destination that is provided by a user (step S101). The mobile apparatus 52 then detects the present position of a vehicle in which the mobile apparatus 52 is mounted thereon (step S102). The mobile apparatus 52 then provides the inputted destination and the detected present position to the server 51 side (step S103). Information for identifying a registered member or registered mobile apparatus 52 (hereinafter, registration identifier) is added to the present position and destination provided by the mobile apparatus 52. The mobile apparatus 52 then executes step S110, which will be described below.

[0087] In FIG. 3B, the server 51 receives the information that is provided by the mobile apparatus 52 in the above described manner (that is, the destination and present position) (step S104). The server 51 stores a registration check table for checking a registration identifier that is added to the information against registration identifiers in the table to determine whether the user is a registered member or not (step S105). If No, the procedure goes to step S114. Alternatively, before step S114, the server 51 may send a message that prompts the user for registration.

[0088] If Yes in step S105, the server searches for an optimal route from the present position to the destination (step S106). For this route search, Dijkstra's algorithm as stated in Background Art section (refer to FIG. 19), Dijkstra's algorithm using weights (refer to FIG. 20), and other algorithms are used.

[0089] The server 51 stores map data and its related information.

The related information includes, for example, weather forecast, traffic jam information, the locations of parking lots and whether the parking lots have any vacancy, and various buildings and events. The server 51 selects, from the stored information, map data including the optimum route found in step S106 and its related information (step S107). Such map data includes, by way of example only, two types of map data, that is, a wide-area map and a detailed map around the route. The related information includes, also by way of example only, weather forecast and parking lot information around the area covered by the map data.

[0090] Next, the server 51 calculates the amount of and the charge for the information to be provided to the user of the mobile apparatus 52 (that is, the amount of and the charge for the map data and the related information selected in step S107), and bills the user (step S108). In response, the user electronically settles the bill by a credit card, debit card, or the like.

[0091] An issue of importance in this system is how to calculate the amount of charge (billing information) in the billing process of the above-described step S108, which is summarized below.

[0092] In general, a different optimum route is found for each search in step S106. Different routes often have different amounts and types of information selected in step S107. More specifically, the optimum route is found from the starting point (the present position of the mobile apparatus 52 detected in step S102) to the destination inputted in step S101. Based on the distance between

the present position and the destination inputted by the user, the route length varies, and the amount and type of information selected in step S107 usually varies accordingly. In general, different routes of the same length have different amounts and types of information selected.

[0093] Therefore, the server 52 calculates the amount of charge based on the information that is selected in step S107, that is, the information to be transmitted to the mobile apparatus 52. More specifically, the server 52 calculates the amount of charge based on the amount of information that is selected (on an as-used basis). More preferably, varying unit prices per unit amount of information are set for varying types of information, and the amount of charge is calculated based on the unit prices and the amount of information selected. By way of example only, the unit price is set for each sheet of the detailed map or for each Kbyte of the related information.

[0094] Electronic settlement is exemplarily carried out as follows. The server 51 is connected through the communication line network 122 to a host computer of a credit card company, bank, or any other financial institution for notifying the host computer of the amount of charge. The host computer electronically manages the credit or account of the service provider and the user. Notified of the amount of charge, the host computer debits the amount of charge against the user's account, and credits that amount to the provider's account.

[0095] The foregoing description is how to calculate the amount of charge in the billing process in step S108.

[0096] After the billing process in step S108 is completed, the server 51 transmits the information that is selected in step S107 to the mobile apparatus 52 (step S109). The server 51 then executes step S144, which will be described below.

[0097] In FIG. 3A, the mobile apparatus 52 receives the information that is transmitted from the server 51 in the above-described manner (step S110). The received information includes the optimum route, the map data covering the optimum route, and the related information. The mobile apparatus 52 guides the vehicle along the optimum route (step S111). In the route guide, a symbol indicating the present position of the vehicle and the optimum route are overlaid on the map. The related information is also overlaid thereon, as required.

[0098] The mobile apparatus 52 then determines whether the vehicle arrives at the destination (step S112) and, if Yes, ends the operation.

[0099] If No in step S112, the mobile apparatus 52 determines whether the vehicle goes off the area that is covered by the map which corresponds to the map data received from the server 51 in step S110 and stored in the storage 4 (step S113). If No, the procedure returns to step S108, wherein the mobile apparatus 52 continues the route guide along the optimum route.

[0100] If Yes in step S113, the procedure repeats step S101

and the subsequent steps. That is, the mobile apparatus 52 again notifies the server 51 of the present position of the vehicle and the destination. Based on this notification of the present position and the destination, the server 51 again performs a route search, and transmits, to the mobile apparatus 52, a newly found optimum route, map data covering the optimum route, and its related information. Thereafter, the mobile apparatus 52 guides the vehicle along the new optimum route by using the new map data.

[0101] In FIG. 3B, after transmitting the information to the mobile apparatus 52, the server 51 determines whether to continue the operation (step S114). If No, the server 5 ends the operation. If Yes, the procedure returns to step S104.

[0102] In the above-described operation of the interactive navigation system, steps S101 and S102 of FIG. 3A may be executed in reverse order.

[0103] The detailed operation of the system, that is, each of steps S101 to S114 shown in FIG. 3, is next described.

[0104] [Map data and related information stored in the server]

[0105] In FIG. 1, the map data storage 106 of the server 51 stores the map data comprised of positional information about route nodes, roads, buildings (type and shape), streets, natural objects, place names, altitudes, for example, and their related information such as attributes. Such positional information is stored in a two-dimensional coordinate system by latitude and longitude.

[0106] The map data varies in form depending on the mobile

apparatus 52. For this reason, a plurality of types of the map data are stored. The map data storage 106 receives these plurality of types of the map data externally through the input/output part 109 and the communication line network 122, and always holds the most recent map data.

[0107] The related information storage 108 stores the related information such as descriptions of the buildings, events held in shops (a discount sale), traffic jams, parking lots (locations, fees, and vacancy), events, sightseeing spots, and weather forecasts. The related information storage 108 receives such related information externally through the input/output part 109 and the communication line circuit 122 at predetermined time intervals or every time the information is updated, and always holds the most recent related information.

[0108] The related information is stored in the related information storage 108. That is, for example, each piece of related information is accompanied by data indicating latitude and longitude in a two-dimensional coordinate system. The related information generally has a data form that can be browsed through on the Internet.

[0109] [Detecting the present position (step S102)]

The present position detector 2 of the mobile apparatus 52 detects the present position of the vehicle. This detection can be implemented by a so-called GPS (Global Positioning System) receiver, and, more accurately, by a DGPS (Differential Global

Positioning System) receiver.

[0110] The detection by such a GPS receiver can be further improved by incorporating an acceleration sensor or gyroscopic sensor in the vehicle for sensing the distance or the direction traveled. With the sensing results, the present position detected by the GPS receiver can be corrected, and the vehicle can be located even though the vehicle is at a place that is undetectable by the GPS receiver, such as in a tunnel. The detection of the vehicle's present position is carried out at predetermined time intervals (approximately twice to ten times per second). The position detected by the present position detector 2 is sent to the rendering part 8 and the wireless transmitter/receiver 3.

[0111] [Inputting the destination (step S101)]

The operational input part 1 is for the user to enter information composed of the registration identifier, starting point position, destination position, an identifier indicating an optimum-route search method, and an identifier indicating whether the related information is required. If the starting point position is the present position, the user's input is not required because the present position detected by the present position detector 2 is used. The destination point is positionally specified by a place name, building name, address, telephone number, or other information.

[0112] The optimum-route search method identifier indicates which method is to be used for searching the optimum route to the

destination. Available search methods may consider traffic jam, the sights and historic scenes for sightseeing, or a minimum time and minimum distance.

[0113] The related information identifier indicates whether the information that is related to the guide route is required. Such related information includes descriptions of the buildings, events in the shops (a discount sale), traffic jams, parking lots (locations, fees, and vacancy), events, sightseeing, and weather forecasts. The related information also indicates how many details are required (detailed or summarized, for example), and what type of the related information is required.

[0114] When using the service for the first time, the user has to also enter registration information. The registration information includes, by way of example only, a name of the user to be registered, address, an identifier of a user's machine (form of the map data), information for electronically settling a charge (credit card, for example). Alternatively, such registration information may be sent to a billing management organization through a predetermined communication means such as telephone, facsimile, mail, or electronic mail.

[0115] [Providing the present position and destination (step S103)]

The input information entered through the operational input part 1 is sent out, as a packet having the structure as exemplarily shown in FIG. 4, from the wireless transmitter/receiver

3 to the server 51 side. In FIG. 4, the packet is structured by the registration identifier, the present position or starting point position, the destination position, optimum-route search method identifier, and the related information requirement identifier.

[0116] [Receiving the present position and destination (step S104)]

In the server 51, the wireless transmitter/receiver 101 receives the input information that is transmitted from the wireless transmitter/receiver 3 in the above-stated manner. Such transmission and receiving can be implemented by a wireless communication technique used in so-called packet communications. The wireless transmitters/receivers 3 and 101 may be implemented by cell phones.

[0117] [Registration check table held by the server]

In the server 51, the registration check part 102 holds the registration check table having a form as shown in FIG. 5. In FIG. 5, recorded in the registration check table for each registered member are the registration identifier, the registered data form (type), the data amount, the charge amount, the frequency of log-in, the total data amount, and the total billing amount.

[0118] The registration identifier is information for identifying each registered user (hereinafter, registered member).

[0119] The registered data form indicates a data form of the information to be used by the registered member. Since the usable

data form may vary according to the type of the mobile apparatus 52, the data form that is suitable for the user's machine (mobile apparatus 52) is registered in advance in the server 51 side, and the information in such data form is transmitted.

[0120] The data amount indicates the amount of information that is provided to the registered member in the previous service. The charge amount indicates the amount of charge for the information that is transmitted to the registered member in the previous service. The charge amount is calculated based on the data amount and billing information (as will be described below). The frequency of log-in indicates how many times or how long the registered member has logged in to the server 51, and is represented by the number of times of log-in or a log-in time period.

[0121] The total data amount indicates the total amount of information that was provided to the registered member until the present time. The total billing amount indicates the total amount of billing for the information transmitted to the registered member until the present time.

[0122] [Checking whether the user is a registered member (step S105)]

Referring back to FIG. 1, the registration check part 102 checks, against the registration check list of FIG. 5, the registration identifier that is included in the input information received by the wireless transmitter/receiver 101. If the check result shows that the user is a registered member, that is, if

the registration identifier that is included in the input information is recorded in the list, the registration check part 102 determines that the service is to be provided. Then, the registration check part 102 retrieves the registered data form for the registered member, and notifies the map data selector 105 of the data form. On the other hand, if the user is not a registered member, the registration check part 102 notifies the user through the wireless transmitter/receiver 101 that the service is not available. If the user uses the system for the first time, a new registration identifier is assigned to the user, and is added to the registration check list together with a registered data form for the user.

[0123] Then, if it is determined that the service is to be provided after checking against the registration check list, a route search is performed.

[0124] [Searching for the optimum route (step S106)]

Of the input information that is received by the wireless transmitter/receiver 101, the starting point position (present position), the destination position, and the optimum-route search method identifier are provided to the route search part 104, and the related information requirement identifier is provided to the billing part 103 and the map data selector 105.

[0125] When receiving the starting point position (present position), the destination position, and the optimum-route search method identifier, the route search part 104 first reads the map

data that is stored in the map data storage 106 for specifying the starting point position and the destination position. In other words, the route search part 104 specifies the absolute positions of the starting point and the destination by latitude and longitude, for example, based on the starting point and the destination which is represented by address, place name, or telephone number. The map data to be used for specifying the positions may be the one dedicated to position specification.

[0126] The dedicated map data is quickly searchable data such as an address directory, place-name directory, or telephone directory. In each such directory, addresses, place names, and/or telephone numbers are registered in relation to the information that can specify absolute positions such as longitude and latitude.

[0127] If the absolute positions of the starting point and the destination cannot be uniquely specified only by the positional information that is included in the input information, the following procedure is taken. That is, the route search part 104 first finds a plurality of potential positions based on the positional information that is included in the input information. Then, the route search part 104 transmits the potential positions to the mobile apparatus 52 side through the wireless transmitter/receiver 101.

[0128] In the mobile apparatus 52, the wireless transmitter/receiver 3 receives the potential positions transmitted from the server 51, and sends the received potential

positions to the rendering part 8. The rendering part 8 renders images for the potential positions to be displayed on the display part 9. The user sees the images for the potential positions displayed on the display part 9, thereby allowing the user to be able to determine which position is correct. Then, the user selects the correct position via the operational input part 1.

[0129] Once the absolute positions are specified by the user's selection among the potential positions, the operational input part 1 provides the specified absolute positions of the starting point and the destination to the server 51 side through the wireless transmitter/receiver 3. In the server 51, the wireless transmitter/receiver 101 receives the specified positions, and notifies the route search part 104 of the specified positions.

[0130] Upon recognizing the absolute positions, the route search part 104 sends data indicating these absolute positions (longitude and latitude information, for example) to the map data selector 105. Based on the absolute positions that are provided by the route search part 104 and the registered data form that is provided in advance by the registration check part 102, the map data selector 105 reads route node information and road information from the map data that is stored in the map data storage 106. Such route node information and road information cover an area which is defined by the starting point and the destination and have a data form that conforms to the user's registered data form. The map data selector 105 sends the route node information

and road information to the route search part 104.

[0131] The route search part 104 finds an optimum route based on the route node information and road information that are read by the map data selector 105.

[0132] The above optimum route search is performed by using Dijkstra's algorithm preferably with weighting. In Dijkstra's algorithm with weighting, every link composing the route is provided with a weight based on predetermined criteria.

[0133] In Dijkstra's algorithm with weighting, the route search part 104 changes the weight to be provided to every link based on the method indicated by "the optimum-route search method identifier".

[0134] If the optimum-route search method identifier indicates "route search for sightseeing", for example, the route search part 104 refers to the sightseeing information stored in the related information storage part 10 for providing a small weight to every link in the vicinity of sightseeing spots. Thus, the route search part 104 can find a route through the vicinity of the sightseeing spots to the destination.

[0135] If the identifier indicates "route search in consideration of traffic jam", the route search part 104 refers to the latest traffic jam information that is stored in the related information storage 108 for providing a large weight to every link corresponding to a jammed road section. Thus, the route search part 104 can find a route that enables the vehicle to reach the

destination by detouring around the jammed road section.

[0136] Dijkstra's algorithm with weighting has been described in Background Art section.

[0137] [Selecting map data/related information]

The optimum route that is found by the route search part 104 in the above-described manner is provided to the map data selector 105 and the transmission data history storage 111. The transmission data history storage 111 stores the optimum route that is received from the route search part 104 together with a time when the optimum route is received. In other words, the transmission data history storage 111 stores histories of finding the optimum route, that is, when and what route was found as the optimum route.

[0138] Based on the optimum route that is provided by the route search part 104 and the registered data form that is provided in advance by the registration check part 102, the map data selector 105 reads wide-area map data (more reduced map data) and detailed map data (less reduced map data) from the map data that is stored in the map data storage 106. The wide-area map data has a data form that conforms to the user's registered data form, and covers the optimum route. The detailed map data also has a data form that conforms to the user's registered data form, and covers the vicinity of the optimum route.

[0139] One example of the wide-area maps and the detailed maps which are each selectively read by the map data selector 105 is

shown in FIG. 6. In the example of FIG. 6, the optimum route from the starting point to the destination extends over three wide-area maps. Therefore, these three maps are read.

[0140] Each wide-area map is divided into 25 (= 5 × 5) small areas. Of these 25 small areas, the map data selector 105 selects the small area that covers an area satisfying that the distance from the optimum route is within a threshold. In this example, the number of the small areas to be selected is twelve, and only the data for twelve maps that correspond to these twelve small areas are read from the map data storage 106. In other words, the map data selector 105 determines that the detailed map data that covers the area away from the optimum route is not required, and does not read such map data.

[0141] The map data selector 105 also reads the information that is related to the read map data if the related information requirement identifier included in the input information indicates positive. That is, the map data selector 105 determines that the information that is not related to the read map data is not required, and does not read such information. The read map data (including the optimum route) and the related information in the above-described manner are provided to the transmission data compression part 107.

[0142] [Billing (step S108)]

The map data selector 105 also notifies the registration check part 102 and the billing part 103 of the amount of map data

that is read from the map data storage 106 and the type and amount of the related information. The billing part 103 stores a list including a predetermined price schedule. Based on the price list, the billing part 103 calculates the amount of charge (billing information) for the information that is transmitted to the mobile apparatus 52.

[0143] FIGS. 7A and 7B are diagrams each showing a specific example of the price list that is stored in the billing part 103. Described in the price list of FIG. 7A are a unit price per sheet for the map data (10 yen per sheet, for example) and a unit price per area that corresponds to one sheet of map data ("50 yen per area" for the traffic jam information, "20 yen per area" for the event/discount sale information, and "10 yen per area" for the sightseeing information, for example).

[0144] Described in the price list of FIG. 7B are a unit price per Mbyte for the map data ("10 yen per Mbyte, for example) and a unit price per Kbyte for the related information ("50 yen per Kbyte" for the traffic jam information, "20 yen per Kbyte" for the event/discount sale information, and "10 yen per Kbyte" for the sightseeing information, for example).

[0145] FIG. 8A is a diagram showing a specific example of the amount of charge (billing information) that is calculated according to the price list shown in FIG. 7A. FIG. 8B is a diagram showing another specific example of the amount of charge (billing information) that is calculated according to the price list in

FIG. 7B.

[0146] According to the area-based price list of FIG. 7A, the amount of charge can be easily calculated. However, the amount of related information varies depending on the area. For example, the number of roads and shops greatly varies depending on whether the area is urban or suburban. Therefore, the user has to pay the same amount of charge irrespective of the amount of related information that is received.

[0147] On the other hand, if the amount of charge is calculated according to the Kbyte-based price list of FIG. 7B, the user pays the charge in accordance with the amount of related information that is actually received. However, the amount of information has to be strictly managed, and therefore charge calculation becomes burdensome.

[0148] The billing part 103 notifies the registration check part 102 of the calculated amount of charge. Based on the data amount that is provided by the map data selector 105 and the amount of charge that is provided by the billing part 103, the registration check part 102 updates the data amount, the charge amount, the frequency of log-in, the total data amount, and the total billing amount in the registration check list. Then, the registration check part 102 provides the updated contents of the registration check list to the wireless transmitter/receiver 101.

[0149] [Transmitting the optimum route, map data, and related information (step S109)]

The transmission data compression part 107 compresses the map data (including the optimum route) and the related information received from the map data selector 105. This compression process can be executed by using a method generally known such as run-length encoding. The transmission data compression part 107 transmits the compressed data to the wireless transmitter/receiver 101.

[0150] The wireless transmitter/receiver 101 transmits, to the wireless transmitter/receiver 3 of the mobile apparatus 52, the updated contents (billing information) of the registration check list provided by the billing part 103 and the compressed data received from the transmission data compression part 107. The billing information and the compressed data are transmitted as a packet having the structure as shown in FIG. 9, for example.

[0151] The packet shown in FIG. 9 is structured by a public key, the billing information and the compressed data. The billing information and the compressed data are encrypted with the attached public key for preventing an unauthorized use. Well- known public-key encryption systems include the one based on the elliptic curve theory, and the one by factoring. Although the public key encryption system is used in this example, this is not restrictive, and any number of various encryption systems can be used.

[0152] The wireless transmitter/receiver 101 may divide the data into regions, and sequentially transmit these regions in the order of proximity to the starting point. This is effective for

a long route, that is, a large data amount.

[0153] [Receiving the optimum route, map data, and related information (step S110)]

The wireless transmitter/receiver 3 receives the packet that is transmitted from the wireless transmitter/receiver 101, and provides the rendering part 8 with the updated contents (billing information) of the registration check list included in the received packet. Based on the provided billing information, the rendering part 8 generates images indicating the transmission data amount, the charge amount, and other information to be displayed on the display part 9. The compressed data that is included in the received packet is decompressed by the received data decompression part 11. The decompressed data is stored in the storage 4. For displaying the billing information and decompressing the data, a decryption key for decrypting the public-key encryption has to be held by the user.

[0154] [Displaying the route guide and the related information (step S111)]

The route guide in the mobile apparatus 52 side is carried out as follows. Now, the storage 4 stores the decompressed data indicating the wide-area map including the optimum route and the detailed map covering the vicinity of the optimum route. First, the present position detector 2 detects the present position of the vehicle, and notifies the rendering part 8 of the detected position. Also, the user selects a scale through the operational

input part 1, and the rendering part 8 is notified of the selected scale.

[0155] The rendering part 8 reads, from the storage 4, the map data that has a scale which is equal to the selected scale received from the operational input part 1 and which covers the position (the present position of the vehicle) that is received from the present position detector 2. The read map data indicates a wide-area map if a scale for more reduction is selected, and a detailed map if a scale for less reduction is selected. The optimum route and the symbol indicating the present position of the vehicle are overlaid on the map so as to generate an image, and the generated image is displayed on the display part 9.

[0156] The mobile apparatus 52 can also perform a route guide by voice, as a conventional navigation system can do. In a case where the vehicle goes off the optimum route, the route guide part 6 finds a route that is between the present position and an appropriate point on the optimum route (for example, the point that is closest to the present position), and guides the vehicle to return to the optimum route through the found route. In this case, the route guide part 6 may newly find the optimum route from the present position to the destination. Also in this case, a route guide may be performed only with the wide-area maps in certain circumstances.

[0157] Map display may be performed not only by a two-dimensional display technique but also by a three-dimensional

computer graphics technique allowing views such as 3D bird's eye views and views of multilevel intersections. In such a 3D display, the rendering part 8 requires additional functions such as perspective transformation, luminance calculation, mapping, and buffering.

[0158] Furthermore, if any related information that is stored in the storage 4 is of the type that can be overlaid on the map, the rendering part 8 renders images by overlaying the related information to be displayed on the display part 9. Such a type of related information includes traffic jam information, buildings near the route, and information about sightseeing spots. Overlaying the related information on the map is possible because each piece of related information is provided with latitude and longitude information, and therefore, the related information can be positionally linked to the map data.

[0159] On the other hand, if the related information is text data such as a description or image data such as a diagram, images are rendered separately from the map, and are then displayed on the display part 9. If the related information is accompanied by audio data, audio is outputted through the audio output part 7.

[0160] [Reusing received information (not shown)]

After the route guide is thus carried out, the removable-medium drive 10 saves the data that is stored in the storage 4 into a writable storage medium. The saved data can be

read as required for reuse in the next route guide. In this case, when the starting point position (the present position) and destination are inputted through the operational input part 1, the route guide part 6 determines whether the data that is saved into the storage medium can be reused for a route guide.

[0161] If the route guide part 6 determines that the saved data can be reused, the route guide part 6 notifies the user through the display part 9 that the data in the storage medium can be used for the route guide, and also notifies him/her of a saving date.

[0162] On the other hand, if the route guide 6 determines that the saved data cannot be reused or if the user determines, based on the displayed saving date, that a new route search has to be made because the saved date is too old, the route guide part 6 transmits the presently inputted starting point and the destination to the server 51 side. The server 51 side performs the a new route search through the same procedure described above based on the received starting point and the destination, and then transmits new data (optimum route, map data, and related information) to the mobile apparatus 52 side. The mobile apparatus 52 side carries out route guide by using the data newly received from the server 51.

[0163] [Determining whether the vehicle has arrived at the destination (step S112)]

The present position detector 2 detects the present position of the vehicle. The route guide part 6 compares the

detected present position with the destination position. Thus, it is determined whether the vehicle has arrived at the destination.

[0164] [Determining whether the vehicle is out of the area that is covered by the stored data (step S113)]

If No in step S112, that is, if the vehicle has not yet arrived at the destination, the out-of-area determination part 12 refers to the present position that is detected in step S112 and the area that is covered by the map data received and stored in step S110 so as to determine whether the vehicle is out of the area, that is, whether the present position of the vehicle is out of the area that is covered by the map data stored in the storage 4.

[0165] If Yes in step S113, that is, if the vehicle substantially goes off the optimum route to the outside of the area that is covered by the map data stored in the storage 4, the rendering part 8 cannot read the map data from the storage 4. Therefore, the rendering part 8 generates an image indicating that reading the map data from the storage 4 is disabled and such an image is displayed on the display part 9. In this case, the user has to go without a guide until the vehicle returns to the area that is covered by the map data stored in the storage 4. To get around this problem, the user may ask the server 51 through the operational input part 1 to again perform an optimum-route search so as to receive the map data which is required for a new route guide.

[0166] On the other hand, if No in step S113, the route guide

part 6 performs a route guide by using the map data that is stored in the storage 4.

[0167] [Settling the bill (not shown)]

The bill is electronically settled by a credit card, debit card, or the like simultaneously when the service is used based on the amount of charge that is managed in the registration check list. Alternatively, the bill is electronically settled by a credit card, debit card, or the like at a predetermined date based on the total amount of use managed in the registration check list.

[0168] Such an electronic settlement is performed by a host computer of a financial institution which is connected to the communication line network 122, for example. Alternatively, the bill may be settled by the user receiving the bill and going to a financial institution or the like to pay the bill by cash.

[0169] During bill settlement, a discount may be given to the user according to the frequency of log-in, the total data amount, and the total billing amount that are managed in the registration check list. For one example, in order to entice new users, a special discount is given to such new users until they log in for a predetermined time. For another example, in order to promote sales, a special discount is given to users whose frequency of log-in, total data amount, and/or total billing amount exceeds a predetermined threshold.

[0170] In the first embodiment, the server 51 searches for the

optimum route and provides the search results and map data together with the related information. Alternatively, the server 51 may provide only the related information. In this case, the mobile apparatus 52 transmits, to the server 51, the packet shown in FIG. 4 with "no route search" as the optimum-route search method identifier. In this case, the server 51 then does not perform a route search and other processing that is associated with the map data, and transmits only the related information to the mobile apparatus 52.

[0171] Second embodiment

Hereinafter, an interactive navigation system according to a second embodiment of the present invention is described with reference to the drawings. Note that the same components as those in the first embodiment are provided with the same reference numerals.

[0172] FIG. 10 is a block diagram showing the structure of the interactive navigation system according to the second embodiment of the present invention. In FIG. 10, the system includes the server 51, a wireless base station 70, and the mobile apparatus 52. The mobile apparatus 52 includes the operational input part 1, the present position detector 2, the wireless transmitter/receiver 3, the storage 4, the controller 5, the route guide part 6, the audio output part 7, the rendering part 8, the display part 9, the removable-medium drive 10, and the received data decompression part 11.

[0173] The server 51 includes the registration check part 102, the billing part 103, the route search part 104, the map data selector 105, the map data storage 106, the transmission data compression part 107, the related information storage 108, the input/output part 109, the controller 110, and the transmission data history storage 111.

[0174] The wireless base station 70 includes a wireless transmitter/receiver 201, a controller 202, and an input/output part 203.

[0175] The server 51 is connected to the wireless base station 70 through the communication line network 122. The mobile apparatus 52 and the server 51 can interactively and wirelessly communicate with each other through the wireless base station 70. The server 51 can further communicate, also through the communication line network 122, with the outside such as a host computer in a traffic control center or in a financial institution (not shown).

[0176] In other words, the server 51 in the first embodiment wirelessly communicates with the mobile apparatus 52 directly, while the server 51 in the second embodiment communicates with the mobile apparatus 52 through the wireless base station 70. The wireless transmitter/receiver 201 in the wireless base station 70 has a higher output power and sensitivity, and therefore, the service can be available in a wider area.

[0177] The communications between the mobile apparatus 52 and

the server 51 are performed as follows. For data transmission from the mobile apparatus 52 to the server 51, data sent out from the wireless transmitter/receiver 3 of the mobile apparatus 51 is first received by the wireless transmitter/receiver 201 of the wireless base station 70. The data then goes through the input/output part 203, the communication line network 122, and the input/output part 109 to the controller 110 of the server 51.

[0178] On the other hand, for data transmission from the server 51 to the mobile apparatus 52, data is transferred from the input/output part 109 of the server 51 through the communication line network 122 to the input/output part 203 of the wireless base station 70. The data is then sent out from the wireless transmitter/receiver 201, and is then received by the wireless transmitter/receiver 3 of the mobile apparatus 52.

[0179] The interactive navigation system of the second embodiment is similar in operation to that of the first embodiment except for the above-described communications between the mobile apparatus 52 and the server 51. Therefore, a detailed description of the operation of the interactive navigation system of the second embodiment is omitted.

[0180] Third embodiment

Hereinafter, an interactive navigation system according to a third embodiment of the present invention is described with reference to the drawings. Note that the same components as those in the first embodiment are provided with the

same reference numerals.

[0181] FIG. 11 is a block diagram showing the structure of the interactive navigation system according to the third embodiment of the present invention. In FIG. 11, the system includes a server 51a and mobile apparatuses 52a. Of these mobile apparatuses 52a, the mobile apparatus 52a for which the server 51a is going to perform a route search is hereinafter called a target mobile apparatus 52a in order to be distinguishable from the other mobile apparatuses 52a, which are hereinafter called non-target mobile apparatuses 52a. Note that such a distinction is not fixed; that is, one mobile apparatus can be regarded as the target mobile apparatus 52a at one time and the non-target mobile apparatus 52a at another time.

[0182] The mobile apparatus 52a includes the operational input part 1, the present position detector 2, the wireless transmitter/receiver 3, the storage 4, the controller 5, the route guide part 6, the audio output part 7, the rendering part 8, the display part 9, the removable-medium drive 10, and the received data decompression part 11.

[0183] The server 51a includes the wireless transmitter/receiver 101, the registration check part 102, the billing part 103, a route search part 104a, the map data selector 105, the map data storage 106, the transmission data compression part 107, the related information storage 108, the input/output part 109, the controller 110, the transmission data history storage

111, and a mobile apparatus position route manager 112.

[0184] The mobile apparatus 52a and the server 51a can interactively and wirelessly communicate with each other through the respective wireless transmitter/receivers 3 and 101. The server 51a can further communicate, through the communication line network 122, with the outside such as a host computer in a traffic control center or in a financial institution (not shown).

[0185] That is, the server 51a of the third embodiment is structured by further providing the server 51 of the first embodiment with the mobile apparatus position/route manager 112 and the route search part 104a instead of the route search part 104.

[0186] The hardware structure of the interactive navigation system of the third embodiment is similar to that of the first embodiment as shown in FIGS. 2A and 2B. However, in FIG. 2B, a program that is partly different from the program in the first embodiment is stored in the ROM 54 of the server 51a side for realizing the functions of the mobile apparatus position/route manager 112 and the route search part 104a, which will be described below.

[0187] The operation of the above structured interactive navigation system according to the third embodiment is now briefly described.

[0188] FIG. 12A is a flowchart showing the operation of the target mobile apparatus 52a; FIG. 12B is a flowchart showing the

operation of the server 51a; and FIG. 12C is a flowchart showing the operation of the non-target mobile apparatuses 52a. The operations of the target mobile apparatus 52a and the non-target mobile apparatuses 52a shown in FIGS. 12A and 12C, respectively, are realized by the controller 5 performing operations and controlling other components (1 to 4, and 6 to 12). The operation of the server 51 shown in FIG. 12B is realized by the controller 110 performing operations and controlling other components (101 to 109, and 111, 112).

[0189] In FIG. 12C, each non-target mobile apparatus 52a detects the present position of the respective vehicles in which the non-target mobile apparatus 52a is mounted thereon(step S201). The non-target mobile apparatus 52a then sends out the detected present position to the server 51 (step S202). These detection and sending processes are performed periodically (twice to ten times per second, for example). Alternatively, these detection and sending processes may be performed in response to a request from the server 51a.

[0190] In FIG. 12B, the server 51a receives the present position from the non-target mobile apparatus 52a (step S203). The server 51a stores a position/route management table for managing the present position and the optimum route for each mobile apparatus 52a. The optimum route is the one found in step S106a when the mobile apparatus 52a is regarded as the target mobile apparatus 52a. Based on the present position that is received in step S201,

the position/route management table is updated (step S204). The mobile apparatus position/route management process in steps S201 and S202 is continuously performed until a route search request is transmitted from the target mobile apparatus 52a.

[0191] The series of operations from steps S101 to S103 and S110 to S113 that are performed by the target mobile apparatus 52a shown in FIG. 12A are similar to those shown in FIG. 3A. In FIG. 12B, the series of operations from steps S104, S105, S107 to S109, and S114 that are performed by the server 51a in response to the request from the target mobile apparatus 52a are similar to those shown in FIG. 3B, except route search (step S106a) and position/route recording (step S106b). Note that, in the third embodiment, the billing process in step S108 does not have to be required. When the billing process is not performed, the packet to be transmitted in step S109 has the structure as shown in FIG. 13, wherein billing information (the amount of charge) is not included.

[0192] Similar to the first embodiment, the server 51a finds, in step S106a, the optimum route by using Dijkstra's algorithm with weighting. The weight to every link is different, however, from that in the first embodiment. That is, the server 51a refers to the mobile apparatus position/route management table for calculating the weight for each link based on the present position and the optimum route of the non-target mobile apparatuses 52a.

[0193] In step S106b, based on the present position that is

received in step S104 and the optimum route that is found in step S106a, the server 51a updates the mobile apparatus position/route management table. The procedure then goes to step S107.

[0194] The operation of the interactive navigation system according to the third embodiment has been briefly described above. Note that the steps S101 and S102 of FIG. 3A may be executed in reverse order.

[0195] Next, each of steps S201 to S204 shown in FIG. 12C and steps S106a and S106b shown in FIG. 12B are now described.

[0196] [Detecting the present position of the non-target mobile apparatuses 52a]

In each of the non-target mobile apparatuses 52a, the present position detector 2 detects the present position of the respective vehicles in which the non-target mobile apparatus 52a is mounted thereon. This present position detection is performed at predetermined time intervals (twice to ten times per second, for example). The position that is detected by the present position detector 2 is provided to the rendering part 8 and the wireless transmitter/receiver 3.

[0197] [Providing the present position (step S202)]

The present position that is detected by the present position detector 2 of the non-target mobile apparatus 52a is sent out from the wireless transmitter/receiver 3 to the server 51a side.

[0198] [Receiving the present position (step S203)]

In the server 51a, the wireless transmitter/receiver 101 receives the detected present position from the wireless transmitter/receiver 3 of the non-target mobile apparatus 52a.

[0199] [The mobile apparatus position/route management table held by the server]

In the server 51, the mobile apparatus position/route manager 112 holds the mobile apparatus position/route management table having a form as exemplarily shown in FIG. 14. In FIG. 14, the present position and the optimum route for each mobile apparatus 52a is recorded in the mobile apparatus position/route management table.

[0200] The present position in this mobile apparatus position/route management table indicates the most recent position of the mobile apparatus 52a that is received in step S203 by the server 51a. The optimum route is the route that is found in step S106a when one mobile apparatus 52a is regarded as the target mobile apparatus 52a.

[0201] [Recording the position of the non-target mobile apparatuses in the mobile apparatus position/route management table (step S204)]

The mobile apparatus position/route manager 112 records the present position of the non-target mobile apparatuses 52a received in step S203. Alternatively, the mobile apparatus position/route manager 112 may update the contents of the mobile apparatus position/route management table.

[0202] [Searching for the optimum route (step S106a)]

Among the input information that is received by the wireless transmitter/receiver 101, the starting point position (present position), the destination position, and the optimum-route search method identifier are sent out to the route search part 104a, while the related information requirement identifier is sent out to the map data selector 105.

[0203] Upon being notified of the above-described information, the route search part 104a first reads the map data that is stored in the map data storage 106 for specifying the starting point position and the destination point. This specifying process is similar to the specifying process in the first embodiment, and is not described herein.

[0204] After specifying the absolute positions of the starting point and the destination, the route search part 104a sends data indicating these absolute positions (longitude and latitude information, for example) to the map data selector 105. Based on the absolute positions that are provided by the route search part 104a and the registered data form that is provided in advance by the registration check part 102, the map data selector 105 reads route node information and road information from the map data that is stored in the map data storage 106. Such route node information and road information cover an area that is defined by the staring point and the destination and have a data form that conforms to the user's registered data form. The map data selector 105 sends

the route node information and the road information to the route search part 104a.

[0205] The route search part 104a calculates the optimum route based on the route node information and the road information read by the map data selector 105 and the mobile apparatus position/route management table.

[0206] The route search part 104a performs an optimum route search by using Dijkstra's algorithm with weighting. The basic procedure is similar to that in the first embodiment, but the procedure is different in that the route search part 104a calculates weights that are provided to the links composing the route according to the following weight calculation method which mainly characterizes the route search of the present embodiment.

[0207] If the optimum-route search method identifier indicates "route search in consideration of traffic jam", the route search part 104a refers to the latest traffic jam information that is stored in the related information storage 108 for providing an additional weight on each link composing a route that is jammed at this moment. Such weighting is hereinafter referred to as first weighting. The weight provided on each link in the first weighting is determined so as to be increased more when the route becomes more jammed. This process is similar to that in the first embodiment.

[0208] In addition, the route search part 104a refers to the present position and the optimum route in the mobile apparatus

position/route management table for providing an additional weight onto each link composing a route the non-target mobile apparatuses 52 will pass through. Such weighting is hereinafter referred to as second weighting. The weight provided onto each link in the second weighting is determined so as to be increased with the number of non-target mobile apparatuses 52 that will simultaneously pass through that link is presumed to increase. This second weighting is a main characteristic of this route search in the third embodiment.

[0209] FIG. 15 is a flowchart showing one detailed example of step S106a of FIG. 12B (optimum-route search performed by the route search part 104a). In FIG. 15, the route search part 104a calculates a weight for each link based on the present traffic jam information that is externally provided through the communication line network 122 (step S301). Next, the weight calculated in step S301 (hereinafter, first weight) is provided onto to each link. Then, based on the starting point and destination received in step S104 from the target mobile apparatus 52a, a plurality of reachable routes each positionally connecting the starting point and the destination are found (step S302). Here, a predetermined number (ten, for example) of routes are found as the reachable routes in the order of time taken for the target mobile apparatus 52a to reach the destination, the minimum time being the first route.

[0210] Next, the route search part 104a calculates, for each

of the reachable routes found in step S302, a time when the target mobile apparatus 52a will pass through each link composing the route at a predetermined speed such as a legal speed (step S303). Then, the route search part 104a determines whether the times are calculated for every reachable route (step S304). If No in step S304, the procedure returns to step S303, and the route search part 104a calculates, for each remaining reachable route, the time when the target mobile apparatus 52a will pass through each link.

[0211] If Yes in step S304, the route search part 104a calculates, for one of the links composing the route for which the time has been calculated in step S303, how many non-target mobile apparatuses 52a will pass through the link at a predetermined speed such as a legal speed simultaneously when the target mobile apparatus 52a passes the link (step S305). This step is performed based on the present position of every non-target mobile apparatus 52a and the optimum route that is found for every mobile apparatus 52. Then, the route search part 104a determines whether the number has been calculated for every link (step S306). If No in step S306, the procedure returns to step S305, and the route search part 104a calculates, for each remaining link, how many non-target mobile apparatuses 52a will pass through the link.

[0212] If Yes in step S306, the route search part 104a calculates a weight for each link based on the calculation result in step S305 (step S307). That is, the route search part 104a calculates a weight according to the number of non-target mobile apparatuses

52a that will presumably pass simultaneously when the target mobile apparatus 52 will pass. Such a number of non-target mobile apparatuses 52 is hereinafter referred to as the number of presumed passing apparatuses. The weight may be calculated, by way of example only, in proportion to the number of presumed passing apparatuses. Specifically, for example, the weight is 0 if the number of presumed passing apparatuses is 0; 0.1 if the number is 1; and 0.2 if the number is 2.

[0213] Next, based on the starting point and destination provided in step S104 by the target mobile apparatus 52a, the route search part 104a finds the optimum route connecting the starting point position to the destination position (step S308). The procedure then returns to the flowchart of FIG. 12B.

[0214] The following is a description of the optimum-route search process in the present embodiment.

[0215] Here, Dijkstra's algorithm with weighting is specifically described, which is unique to the present invention. A general optimum-route search by using Dijkstra's algorithm has been described in the Background Art section with reference to FIG. 19. An optimum-route search with Dijkstra's algorithm using the first weight has also been described in the Background Art section with reference to FIG. 20.

[0216] FIG. 16 is a diagram demonstrating an optimum-route search by using Dijkstra's algorithm with the first and second weights. In a route graph of FIG.16, as in the route graph of

FIG. 20, some links have a first weight "aij" added to their predetermined link length. The first weight is calculated based on present traffic jam information. Also, some links have a second weight "bij" added to their predetermined link length. The second weight is calculated based on the number of presumed passing apparatuses.

[0217] In the route graph of FIG. 16, in addition to the first weight that is calculated based on the traffic jam information externally provided, the second weight "bij" that is calculated based on the number of presumed passing apparatuses is further provided. The traffic jam information indicates the state of the traffic jam for each road section at a previous time. On the other hand, the number of presumed passing apparatuses indicates the number of non-mobile apparatuses 52a that will presumably pass through each road section at a future time. In other words, a route search in the third embodiment is performed in consideration of the future movement of the non-target mobile apparatuses 52a. Therefore, the optimum route is found more accurately as compared with the route search that is based on only the traffic jam at a previous time. Thus, the vehicle can be prevented from running into a traffic jam and arriving late.

[0218] [Recording the target mobile apparatus position and route in the mobile apparatus position/route management table (step S106b)]

The mobile apparatus position/route manager 112 records,

for the target mobile apparatus 52a, the present position that is received in step S104 and the route that is found in step S106a in the mobile apparatus position/route management table, or updates the contents of that table.

[0219] Fourth embodiment

Hereinafter, an interactive navigation system according to a fourth embodiment of the present invention is described with reference to the drawings. Note that the same components as those in the first to third embodiments are provided with the same reference numerals.

[0220] FIG. 17 is a block diagram showing the structure of the interactive navigation system according to the fourth embodiment of the present invention. In FIG. 17, the system includes the server 51a, the wireless base station 70, and the mobile apparatus 52a. The mobile apparatus 52a includes the operational input part 1, the present position detector 2, the wireless transmitter/receiver 3, the storage 4, the controller 5, the route guide part 6, the audio output part 7, the rendering part 8, the display part 9, the removable-medium drive 10, and the received data decompression part 11.

[0221] The server 51a includes the registration check part 102, the billing part 103, the route search part 104a, the map data selector 105, the map data storage 106, the transmission data compression part 107, the related information storage 108, the input/output part 109, the controller 110, the transmission data

history storage 111, and the mobile apparatus position/route manager 112. The wireless base station 70 includes the wireless transmitter/receiver 201, the controller 202, and the input/output part 203.

[0222] The server 51a is connected to the wireless base station 70 through the communication line network 122. The mobile apparatus 52a and the server 51a can interactively and wirelessly communicate with each other through the wireless base station 70. The server 51a can further communicate, also through the communication line network 122, with the outside such as a host computer in a traffic control center or in a financial institution (not shown).

[0223] In other words, the server 51a in the third embodiment wirelessly communicates with the mobile apparatus 52a directly, while the server 51 in the fourth embodiment communicates with the mobile apparatus 52a through the wireless base station 70. The wireless transmitter/receiver 201 in the wireless base station 70 has a higher output power and sensitivity, and therefore, the service can be available in a wider area.

[0224] The communications between the mobile apparatus 52a and the server 51a are performed in the manner similar to that of second embodiment. The interactive navigation system of the fourth embodiment is similar in operation to that of the third embodiment except for the above communications. Therefore, a detailed description of the operation of the interactive navigation system

of the fourth embodiment is omitted.

[0225] While the present invention has been described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is to be understood that numerous other modifications and variations can be devised without departing from the scope of the present invention.